Jin MURATA*:

Three subspecies of *Arisaema flavum* (Forssk.) Schott (Araceae)

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キバナテンナンショウの地域的分化と分類

Arisaema flavum (Forssk.) Schott is a peculiar species which is characterized by a very small spathe, congested male flowers, each consisting of a stamen, and a very short spadix-appendage. Although change in the sexuality of inflorescences during the growth of a single plant in successive years, from male to female or monoecious, has been widely observed in the species of *Arisaema* (Maekawa 1924, Bierzychudek 1982, etc.), this species has always been described as monoecious (Hara 1971, Li 1979a, Murata 1984, Mayo & Gilbert 1986). Based on the morphological distinction above, recent authors recognized a monotypic section *Dochafa* consisting of this species (Hara 1971, Li 1979a, Murata 1984).

Arisaema flavum is one of the most widespread species in the genus found in China (Tibet, Sichuan and Yunnan), Himalayan regions (Bhutan, Nepal, Afganistan and adjacent places of India), Southern Arabia (Oman, Yemen and Saudi Arabia), and Africa (Ethiopia), and it was considered to be very constant throughout its range (Mayo & Gilbert 1986). Recently, however, I had an opportunity to examine many specimens from various localities, including a mass collection from Tibet obtained through The Tohoku University China Expedition 1986 and found this species is quite diverse. As a result of extensive herbarium studies and life history observations in cultivated materials, three allopatric subspecies, subsp. *flavum*, subsp. *tibeticum* and subsp. *abbreviatum*, are recognized and discriminated by the size of the spathe and mode of sex change.

Materials and methods Herbarium specimens deposited in A, BM, E, KYO, KUN, NY, TI and TUS were studied. Morphological information on the living plants of two populations of *Arisaema flavum* in Tibet, obtained through field observation by The Tohoku University China Expedition 1986, was analized by reference to voucher herbarium specimens kept at TUS. Observations for various stages of the life history were made on the plants of *A. flavum* collected

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from the western Himalayas and Arabia (Yemen) and cultivated in the Botanical Gardens, Faculty of Science, the University of Tokyo. Root tips of the plants cultivated in the Botanical Gardens, as well as those collected and fixed in the field of Tibet, were used for observation of somatic chromosomes. After pretreatment with 1% colchicine for 4 hours at room temperature, the material was fixed in a 2: 1: 1 mixture of absolute alcohol, acetic acid and chloroform. They were then macerated in a 1: 1 mixture of 1N HCl and 45% acetic acid, stained with Schiff solution and squashed.

Result and discussion Phyllotaxis. In previous studies by Murata (1984, 1988), phyllotaxis was recognized to be a diagnostic character of sections in *Arisaema*. Two types of phyllotaxis were observed in the genus: a quincuncial arrangement with a divergence angle of 2/5 and a spirodistichous arrangement with a divergence angle of about 1/2. Phyllotaxis in *Arisaema flavum* was recognized as quincuncial based on the examination of Himalayan plants. In this study, however, plants of *A. flavum* from China (Tibet) and Arabia (Yemen) were examined and found to have a divergence angle of 2/7 and 2/5, respectively.

Size of spathe and mode of sex change. As is commonly seen in the species of *Arisaema*, the size of plants of *Arisaema flavum* varies widely depending on the condition of the plant. Spathe size, however, is one of the least variable characters and is recognized as an effective taxonomic character.

Arisaema flavum has been described previously as monoecious (Hara 1971, Li 1979a, Murata 1984, etc.). Indeed, the Himalayan plants cultivated in the Botanical Gardens of the University of Tokyo always produce a monoecious (bisexual) inflorescence when they reach maturity. Male inflorescences have never been observed. In these cultivated plants, the spathe is generally small and the spathe blade is always less than 2.0 cm long by 1.2 cm wide. Plants from the Central and West Himalayas (Nepal, Simla & Dehra-Dun in India, and Afganistan) and Oman, excepting extraordinarily large individuals, also have a small spathe, less than (3.0–)2.5 cm long by (1.8–)1.4 cm wide (Fig. 1, subsp. *abbreviatum*), and never produce a male spadix. In specimens from the Yemen, Saudi Arabia and Ethiopia, no male spadix has been observed, while the spathe is distinctly larger than the plants in the Central and West Himalayas and Oman; the spathe-blade is usually more than (2.5–)3.5 cm long by (1.1–)1.6 cm wide (Fig. 1, subsp. *flavum*).

Plants from China (Yunnan, Sichuan and Tibet) and East Himalayas (Bhutan

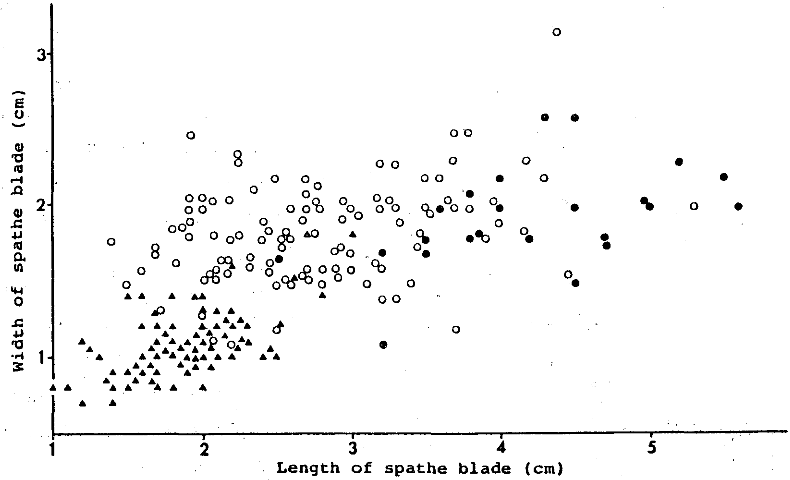

Fig. 1. Variation in size of the spathe blade of *Arisaema flavum* subsp. *flavum* (solid circles), subsp. *abbreviatum* (solid triangles) and subsp. *tibeticum* (open circles). Measurements were made on herbarium specimens.

and Assam in India) also have a large spathe usually more than (1.1–)1.6 cm wide but the length is generally shorter than (4.4–)4.0 cm (Fig. 1, subsp. *tibeticum*). It is a characteristic of the plants of these regions that male spadices commonly occur. For example, out of 57 flowering specimens taken from Tibet (Naito et al. 1510), 24 are males and, according to measurements made in the field, the males were found to be generally smaller than females (Fig. 2). Although critical plant size to induce sex change is not clear from the observations, they nonetheless suggest that the change from male to monoecious inflorescence takes place in East Himalayan and Chinese plants just as is generally found in other species of *Arisaema*.

Three subspecies with allopatric distribution are thus recognized here based on the difference in spathe size and occurrence of sex change in the inflorescence (Tab. 1, Fig. 3).

Chromosome numbers. Chromosome number has been studied in plants taken from three different localities. For subsp. *abbreviatum* from the Himalayas, a tetraploid number 2n=56 has been reported (Murata & Iijima 1983). For subsp. *tibeticum* from Tibet and subsp. *flavum* from Yemen, the numbers were determined in the present study as 2n=28 (Naito et al. 1510, Fig. 4B) and 2n=56

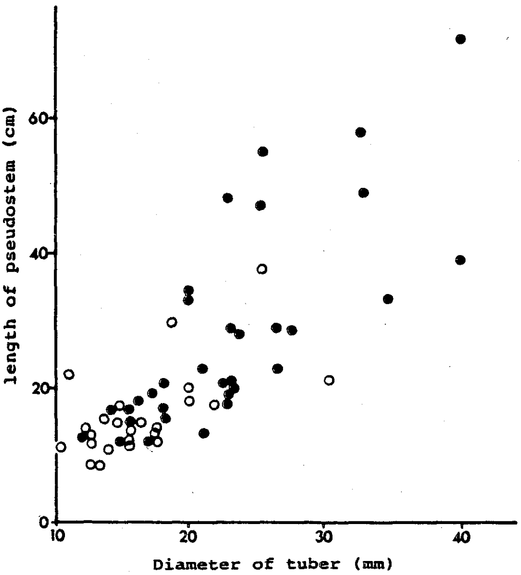

Fig. 2. Size and sexuality of *Arisaema flavum* subsp. *tibeticum*. Monoecious and male plants are represented by solid and open circles, respectively. Measurements were made on living material in Tibet, China.

(Radcliffe-Smith & Henchie 4482, K, Fig. 4A), respectively. It may be hypothesized, therefore, that subsp. *abbreviatum* and subsp. *flavum* with tetraploid chromosomes were differentiated from diploid subsp. *tibeticum*, which implies in turn that in *A. flavum* constantly monoecious inflorescences constitute an apomorphic character state in comparison to sex change in inflorescences (from male to monoecious). Such a correlation of inflorescence sexuality and ploidy level is known in *Arisaema heterophyllum*, where diploid plants and dodecaploid (or decaploid) plants have female and monoecious (bisexual) spadices, respectively when fully mature (Murata & Iijima 1983). This fact suggests that in *A. heterophyllum* a

Tab. 1. Characteristics of the three subspecies of *Arisaema flavum*.

	ssp. *flavum*	ssp. *abbreviatum*	ssp. *tibeticum*
Chromosome numbers	2n=56	2n=56	2n=28
Phyllotaxis	2/5	2/5	2/7
Sex	monoecious	monoecious	paradioecious
Length of spathe blade (cm)	(2.5-)3.5-5.6	1.0-2.5(-3.0)	1.5-4.0(-5.2)
Width of spathe blade (cm)	(1.0-)1.6-2.8	0.6-1.4(-1.8)	(1.0-)1.5-2.5(-3.7)
Distribution	Arabia (Yemen & Saudi Arabia), Africa (Ethiopia)	Central & Western Himalayas (Nepal to Afganistan), Arabia (Oman)	China (Southeastern Tibet and adjacent Sichuan & Yunnan), Eastern Himalayas (Bhutan & Assam)

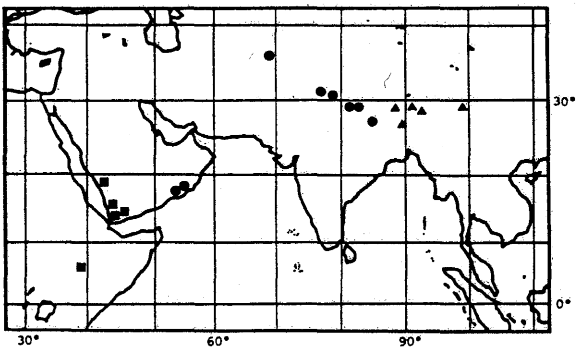

Fig. 3. Distribution of *Arisaema flavum* subsp. *flavum* (solid square), subsp. *abbreviatum* (solid circle) and subsp. *tibeticum* (solid triangle). Dots are based on the representative specimens cited.

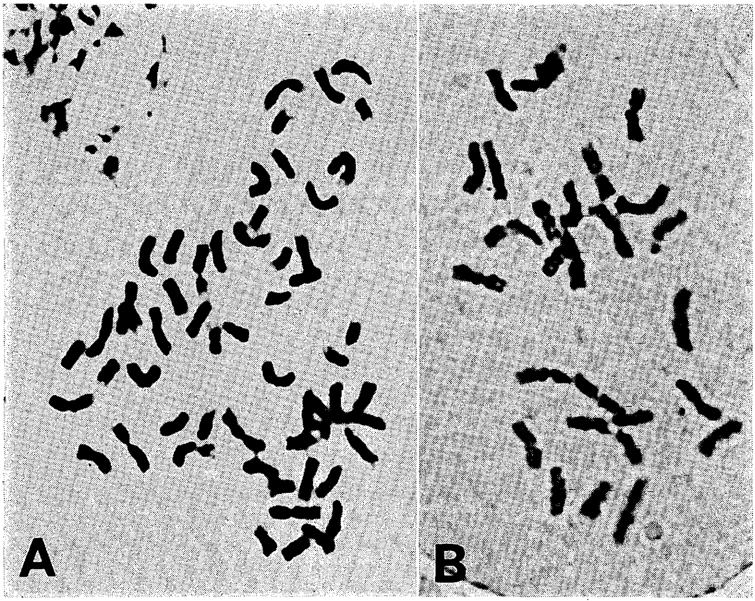

Fig. 4. Somatic chromosomes of *Arisaema flavum*. A: Subsp. *flavum*, 2n=56. (Radcliffe-Smith & Henchie 4482, K). B: Subsp. *tibeticum*, 2n=28. (T. Naito, K. Y. Lang, Y. Tateishi, T. Nemoto & B. S. Li 1510). All ×1000.

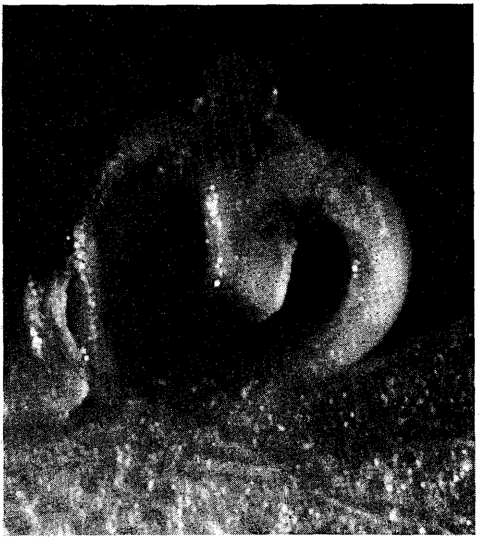

Fig. 5. Vertical section of an ovary of *Arisaema flavum* subsp. *tibeticum*, ovules removed. ×15.

pattern of sex change from male to female is a plesiomorphic character state in comparison to the pattern of male to monoecious (bisexual). In the previous taxonomic studies on *Arisaema*, synapomorphy of the genus has not been indicated. As a result of this study, it has become clear that sex change occurs in sect. *Dochafa* as well as all the other sections of *Arisaema*. As this nature is distinct characteristics of *Arisaema* in Araceae, it is considered to be synapomorphy of this genus which suggests the monophylety of *Arisaema* under current circumscription.

Arisaema flavum (Forssk.) Schott, Prodr. 40 (1860)—Engler in DC., Monogr. Phan. **2**: 548 (1879)—Hook. f., Fl. Brit. Ind. **6**: 503 (1893); Bot. Mag. 126, t. 7700 (1900)—Engler, Pfl.-reich **73** (IV-23F): 172 (1920)—Hand.-Mzt., Symb. Sin. **7**: 1365 (1936)—Schwartz, Mitt. Inst. Allg. Bot. Hamburg **10**: 345 (1939)—Chatterjee, Bull. Bot. Soc. Bengal **8**: 125 (1955)—Kitamura, Fl. Afghan. 62 (1960)—Hara, Fl. East. Him. 2: 344 (1971)—H. Li, Fl. Reip. Pop. Sin. **13**(2): 165 (1979); Fl. Yunnan. **2**: 825 (1979); Fl. Xizan. **5**: 473 (1987).

Arum flavum Forssk., Fl. Aeg.-Arab. CXX, no. 525, Centuria VI, no. 5, p157 (1775)—Christensen, Dansk Bot. Arkiv **4**(3): 27 (1922). Type: North Yemen, Jebel Sobr near Ta'izz, Forsskål s. n. (holotype C).

Dochafa flava (Forssk.) Schott, Syn. Aroid. 24 (1856).

Tuber subglobose. Foliage leaves 1 to 3, pedately 5-11 foliolate; leaflets oblong-lanceolate or obovate-oblong, acuminate at apex, cuneate at base; rachis between leaflets developed, usually winged; petiole usually shorter than pseudostem. Inflorescence monoecious (bisexual) in mature plants, peduncle as long or longer than petiole, usually bent down after flowering. Spathe yellow; tube sometimes greenish, broadly cylindric, constricted apically, 0.9–1.8 cm long, 1–1.5 cm in diameter; blade usually bright yellow tinged with purple at base within, triangular-ovate to ovate, as long or longer than tube. Male flowers congested, subsessile, consisting of a stamen with 2 anthers dehiscent by slit and opening to a pore. Female flower subglobose, with pendulous column inside (Fig. 5); ovules erect, usually 4. Spadix-appendage less than (7–)4 mm long.

subsp. **flavum**

Plant usually large, up to 75 cm tall. Terminal leaflet 3.0–10.5 cm long, 0.6–3.8 cm wide. Spathe-blade narrowly ovate, long acuminate, (2.5–)3.5–5.6 cm long, (1.0–)1.6–2.8 cm wide. Spadix always monoecious (bisexual). Chromosome numbers 2n=56.

Representative specimens. See Mayo & Gilbert (1986), excluding the specimen from Oman.

Distribution. Arabia (Yemen & Saudi-Arabia), Africa (Ethiopia).

subsp. **abbreviatum** (Schott) J. Murata, comb. nov.

Arisaema abbreviatum Schott, Oest. Bot. Zeitschr. 7: 382 (1857)—Schott, Prodr. 39 (1860). Type: India, Simla, Jul. 1849, Hooker & Thomson s. n. (holotype K).

Plant usually small and slender, up to 40(–50) cm tall. Terminal leaflet 2.5–12 cm long, 0.6–3.8 cm wide. Spathe blade triangular ovate, long acuminate, 1.0–2.5(–3.0) cm long, 0.6–1.4(–1.8) cm wide. Spadix always monoecious (bisexual). Chromosome numbers 2n=56.

Representative specimens. NEPAL: Kali Gandaki, Kalopani (2570 m)—Tukche (2680 m), Jul. 18, 1983, H. Ohba et al. 8330594 (TI), Mugu, 29°47′N, 82°32′E, 11000 ft., Jun. 24, 1968, Stainton 6336 (BM, TI), Muktinath, 12500 ft., Jun. 9, 1954, Stainton, Sykes & Williams 5690 (BM). INDIA, Dehra Dun: Kulu Valley, Jun 14, 1950, Jain & Bharadwaja s. n. (NY). AFGANISTAN: Kurrum valley, Dec. 1879, Aitchson 776 (K). OMAN: Dhofar, J. Qara, Hagaif turn-off on Thamrit road, 830 m, Jul. 26, 1985, Miller 7100 (E).

Distribution. Central & Western Himalayas (Nepal to Afganistan) and Arabia (Oman).

subsp. **tibeticum** J. Murata, subsp. nov., paradioica diploidea (2n=28), spadice masculino vel monoecio. Type. CHINA (Tibet): Nyingchi Xian, Bayi, Yarlungzangbojiang River, ca. 2900 m, Mar. 21, 1986, T. Naito, K. Y. Lang, Y. Tateishi, T. Nemoto & B. S. Li 1510 (holotype TUS, isotypes A, K, PE, TI).

Plant paradioecious, usually large, up to 80 cm tall. Terminal leaflet 1.8–15 cm long, 0.7–4.7 cm wide. Spathe blade ovate to trianguler-ovate, acute to acuminate, 1.5–4.0(–5.2) cm long, (1.0–)1.5–2.5(–3.7) cm wide. Spadix male or monoecious. Chromosome numbers 2n=28.

Representative specimens. INDIA: Assam, Walong, 4000 ft., Feb. 22, 1950, K. Ward 19170 (BM). BHUTAN: Ha, 9100 ft., Jun. 19, 1933, Ludlow & Sherriff 120 (BM). CHINA. Tibet: Lhasa, 12000 ft., May 16, 1943, Ludlow & Sherriff 9491 (BM). Gyangtse, Jul.—Sept. 1904, Walton s. n. (B). Tsungpo valley, Kongbo, 9500 ft., Apr. 19, 1947, Ludlow, Sherriff & Elliot 13525 (BM, K). T. Naito, K. Y. Lang, Y. Tateishi, T. Nemoto & B. S. Li 1510 (type). Yunnan: Mountains N. E. of Atuutyo, 28°35′N, 99°70′E, Jul. 1921, Forrest 20107 (E). Sichuan: Batang Xian, Jinshajian River, ca. 2500 m, May 6, 1986, T. Naito, K. Y. Lang, Y. Tateishi, T. Nemoto & B. S. Li 689 (TUS).

Distribution. China (Southeastern Tibet and adjacent Sichuan & Yunnan), Eastern Himalayas (Bhutan & India (Assam)).

I wish to thank the directors and curators of the herbaria who let me study the specimens in their care and Drs. T. Naito, Y. Tateishi and T. Nemoto of Tohoku University, Sendai, the members of the botanical team of The Tohoku University China Expedition 1986, for giving me the data and materials obtained through their field study in Tibet. Living plants of subsp. *flavum* from Yemen were kindly sent from The Royal Botanic Gardens, Kew. I am grateful to Prof. H. Ohashi of Tohoku University, Sendai, and Dr. S. J. Mayo of Royal Botanic Gardens, Kew, for reading the manuscript of this paper.

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Addendum At the final stage of preparation of this paper, *Arisaema daochengense* P. C. Kao was described from Sichuan, China (Kao 1989, Acta Botanica Yunnanica 11: 309). The general morphology of this species is very similar to *A. flavum* subsp. *tibeticum* but differs from the latter in having unisexual (female or male) spadix.

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キバナテンナンショウ *Arisaema flavum* は中国西部からチベット・ヒマラヤ地域を経て北東アフリカまで広く分布する。従来本種は，分布域全体を通じて形態的に比較的均一と考えられてきたが，チベットでの東北大学日中友好西蔵学術登山隊植物班による現地調査の結果も含め，多くの資料について検討したところ，外部形態および性表現の違いにより，地域的にまとまりのある3亜種が認められた (Tab. 1, Fig. 3)。現在まで調べた限りでは染色体数と性表現には関連があり，常に両性の花序を持つ subsp. *flavum* と subsp. *abbreviatum* は共に4倍体 (2n=56) であった。これに対し，小型の個体は雄花序をつけ大型の個体は両性の花序をつけることからいわゆる性転換を行っていると推定される subsp. *tibeticum* は2倍体 (2n=28) であった。従って本種は本来性転換という性質を持っていたが，その後，常に両性の花序を持つ4倍体を生じたと考えられる。従来の分類学的研究では共有派生形質に基づくテンナンショウ属の単系統性が検討されたことはなかったが，性転換という性質はこの属で一般的に見られ，しかもサトイモ科では他に知られていない性質であり，テンナンショウ属の共有派生形質としてその単系統性を強く示唆すると考えられる。

□ Jones, D. L.: **Ornamental rainforest plants in Australia** 364 pp. 1986. Reed Books Pty. Ltd., New South Wales. ¥6,000. オーストラリアの rainforest は，大陸の北端から東海岸に沿って点在している。著者は栽培家でシダやランについての著書もあり，本書ではそれらは省かれているようだ。樹木の花や果実の美しい写真と簡単な線画および種の記述と栽培上のノートがある。 (金井弘夫)